

AFRRI SR70-7  
JUNE 1970

**AFRRI**  
**SCIENTIFIC**  
**REPORT**

THE EFFECTS OF 15,000 RADS  
PULSED GAMMA- NEUTRON RADIATION  
ON THE BEHAVIORAL PERFORMANCE  
OF MONKEYS (MACACA MULATTA)

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE  
Defense Atomic Support Agency  
Bethesda, Maryland

This document has been approved for public release and sale;  
its distribution is unlimited.

All aspects of investigative programs involving the use of laboratory animals sponsored by DoD components are conducted according to the principles enunciated in the "Guide for Laboratory Animal Facilities and Care", prepared by the National Academy of Sciences - National Research Council.

THE EFFECTS OF 15,000 RADS PULSED GAMMA-NEUTRON  
RADIATION ON THE BEHAVIORAL PERFORMANCE  
OF MONKEYS (MACACA MULATTA)

R. W. YOUNG  
W. L. McFARLAND



W. F. DAVIS, JR.  
Chairman  
Behavioral Sciences Department



HUGH B. MITCHELL  
Colonel, USAF, MC  
Director

ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE  
Defense Atomic Support Agency  
Bethesda, Maryland

## TABLE OF CONTENTS

	Page
Abstract . . . . .	iii
I. Introduction . . . . .	1
II. Procedure . . . . .	1
III. Results . . . . .	2
IV. Discussion . . . . .	5
References . . . . .	7

## TABLE

Table I. Dose and Survival Time . . . . .	3
---	---

## FIGURE

Figure 1. Percent correct performance postirradiation . . . . .	4
---	---

## ABSTRACT

Seven male monkeys trained to a visual discrimination task were exposed to a pulsed 15,000-rad midline tissue dose of gamma-neutron radiation. Of these seven animals, five were unable to perform within 5 minutes postirradiation and remained in a state of total nonperformance until death. The two remaining animals experienced periods of severe performance decrement followed by a return of performance capability which approached the preirradiation value. This performance capability deteriorated rapidly at 58 and 88 minutes postirradiation in these two animals, after which time the subjects failed to perform until death. The median survival time for all animals was 1 hour and 18 minutes.

## I. INTRODUCTION

The literature contains a number of investigations concerning the effects of pulsed gamma-neutron irradiation on the conditioned behavior of monkeys.<sup>1,3-9</sup> A majority of these studies are concerned with doses of 10,000 rads or less and information concerning the ability of monkeys to perform a learned task following a higher radiation exposure is quite limited. In order to provide information currently required by the Army\* this study to determine the performance capabilities of the monkey following exposure to 15,000 rads of pulsed radiation was conducted.

## II. PROCEDURE

Seven male monkeys (Macaca mulatta) weighing from 4.2 to 5.2 kg were used. The animals were maintained in primate chairs and housed in individual isolation cubicles.

The apparatus and training procedures employed have been described in a previous report.<sup>2</sup> The behavioral task was a shock motivated simultaneous visual discrimination. Trials were presented every 10 seconds with each trial being initiated by the simultaneous illumination of two response keys and a 15-watt house light. The animals had 5 seconds in which to respond to the correct key. If the subject failed to respond within the 5-second period or responded to the incorrect stimulus the house light remained on, the stimuli extinguished, a tone was initiated and a brief shock was delivered. If the animal responded correctly the house light and stimuli were extinguished for the remainder of the 10-second trial interval. Trials were presented

---

\* Personal communication, Dr. Charles Davidson, U. S. Army Combat Developments Command, Institute of Nuclear Studies, Fort Bliss, El Paso, Texas 79916

in blocks of 100 and each block was followed by a 3-minute rest period. A block of trials and the following rest period lasted 20 minutes.

Each animal was trained using successive approximation techniques until a criterion of 90 percent correct responses for 600 trials was reached. At this point a base-line test approximating exposure conditions was conducted.

Two to three days after the base-line test the animals were placed in Exposure Room No. 2 of the AFRRI-TRIGA reactor for the radiation exposure. The animals were positioned where previous dose mapping indicated a midline tissue dose (MTD) of 15,000 rads would be received. Dose determinations were obtained by measuring the tissue kerma, free-in-air, and multiplying this value by an experimentally derived factor of 0.85.

Behavioral testing started with a block of 100 trials prior to the exposure. The irradiation exposure occurred simultaneously with the onset of the second block of trials and testing continued for 2 hours (a total of 600 trials). Following this 2-hour period the animals were removed from the exposure room and were subsequently tested at 1-hour intervals until death.

### III. RESULTS

The radiation dose and the survival time for each animal are presented in Table I. These data indicate that the survival times ranged from 34 minutes to 3 hours and 20 minutes postirradiation. The average MTD was 15,300 rads with less than a 3 percent variation among animals.

The performance data for the seven animals are presented in Figure 1. These data indicate that only two of the subjects were capable of performing the task at the

criterion level after the first 5 minutes postirradiation. The performance accuracy for all animals showed an immediate decline after exposure, however, two subjects regained their ability to perform after demonstrating a period of severe performance decrement. The duration of the decrement was approximately 2 and 30 minutes respectively for animals Nos. 179 and 202. The plateau or recovery phase following these decrements lasted approximately 84 minutes for animal No. 179 and approximately 26 minutes for animal No. 202. During this period the performance of both animals approached the base-line level of efficiency. The recovery phase deteriorated rapidly into a period of total nonperformance which terminated in death of the subjects.

Clinical observations were made of all animals during the postirradiation period. The symptoms observed included apparently random movement of the head and limbs, nystagmus, pupillary dilatation, vocalization and body movements in response to the electrical shock. Vomiting was observed in only one animal, No. 181. The gross symptomology was similar for all animals and nothing was observed which has not been previously reported for monkeys exposed to supralethal doses of radiation.

Animal #	Tissue kerma free-in-air (rads)	Midline tissue dose (rads)	Survival time
172	17,882	15,200	1 h, 20 min
179	18,000	15,300	2 h, 20 min
181	18,117	15,400	52 min
182	18,117	15,400	34 min
183	18,000	15,300	1 h, 12 min
202	17,882	15,200	3 h, 20 min
204	17,647	15,000	1 h, 18 min

Table I. Dose and Survival Time



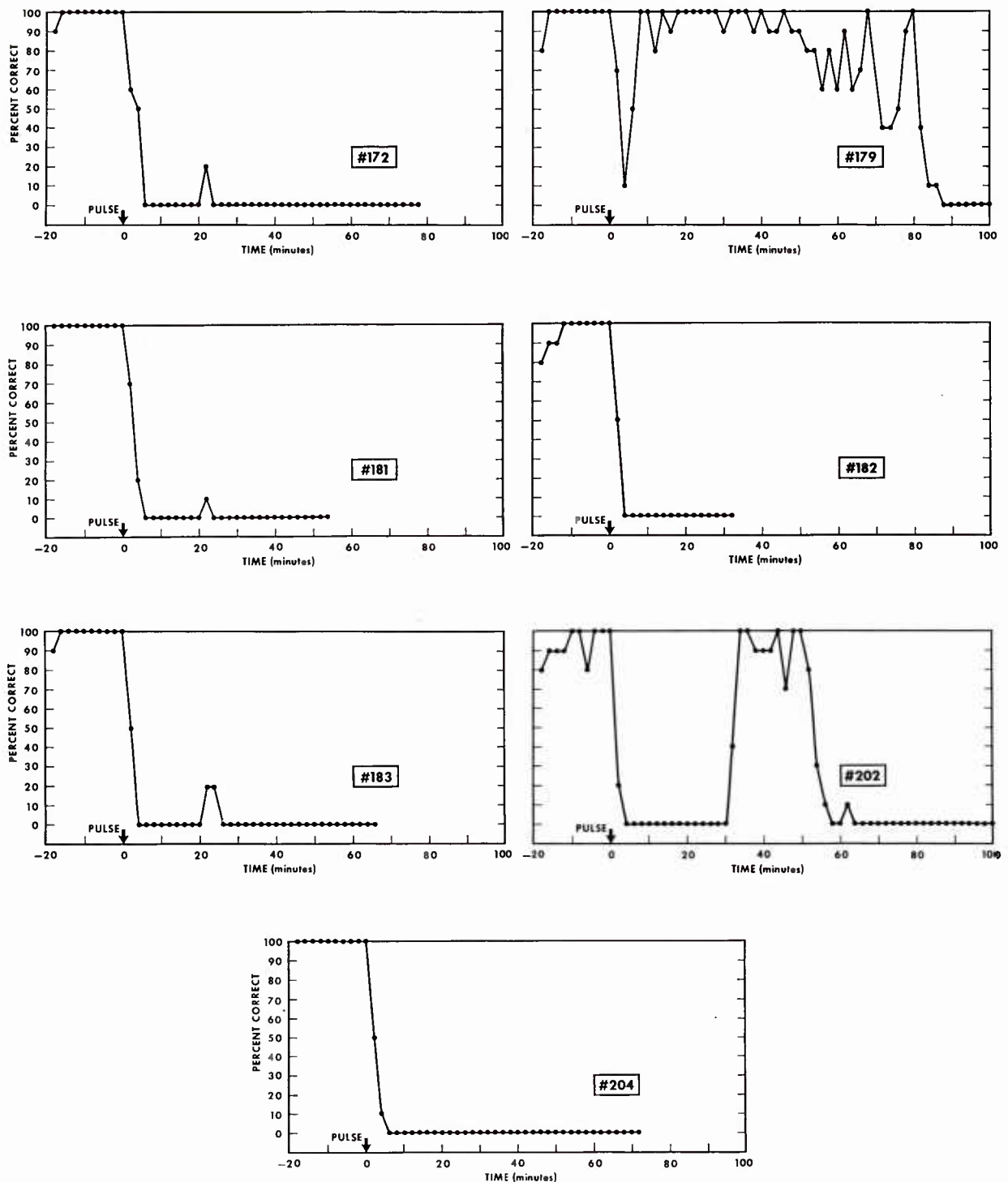


Figure 1. Percent correct performance postirradiation. During each 20-minute interval, 100 trials and a 3-minute rest period were presented. Each point on the graph is the average of 10 trials.

#### IV. DISCUSSION

Germas et al.,<sup>5</sup> reported that following exposure to 10,000 rads of gamma-neutron radiation, monkeys, trained to a similar behavioral paradigm, were capable of accurate task performance as long as 24 hours postirradiation. Of the six animals reported by Germas et al., a total loss of performance capability immediately after exposure was observed for only one. The remaining five animals demonstrated periods of severe performance decrement following which their performance returned to near the preirradiation value. The median time of final performance for these animals was 6.4 hours. In comparison, of the seven animals used in the present study five were unable to perform the learned task within 5 minutes postirradiation and all subjects were incapable of performance within 88 minutes postirradiation.

These data indicate that a total loss of performance capability will be experienced by a large percentage of monkeys immediately following an exposure to a pulsed 15,000-rad MTD of radiation. The data further suggest that the total population will be incapable of completing an assigned task within 2 hours after exposure to a radiation dose of this magnitude.

## REFERENCES

1. Barnes, D. J. An initial investigation of the effects of pulsed ionizing radiation on the primate equilibrium function. Brooks Air Force Base, Texas, U. S. Air Force School of Aerospace Medicine Report TR66-106, 1966.
2. de Haan, H. J. and Germas, J. E. Visual discrimination performance in the monkey (Macaca mulatta): A technique and assessment of 5000 rads gamma-neutron irradiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR68-16, 1968.
3. de Haan, H. J., Kaplan, S. J. and Germas, J. E. Visual discrimination performance in the monkey following a 5,000-rad pulse of mixed gamma-neutron radiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR69-1, 1969.
4. Germas, J. E., Fineberg, M. L. and de Haan, H. J. Visual discrimination performance in the monkey following a 2500-rad pulse of mixed gamma-neutron radiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR69-8, 1969.
5. Germas, J. E., Kaplan, S. J. and de Haan, H. J. Visual discrimination performance in the monkey following a 10,000-rad pulse of mixed gamma-neutron radiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR69-2, 1969.
6. Kaplan, S. J. and Gresko, E. M. The effects of pulsed gamma-neutron radiation upon the performance of the unfettered monkey. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR69-9, 1969.
7. Sharp, J. C. and Keller, B. K. A comparison between the effects of exposure to a mixed fission spectrum delivered in a single "pulse" and x-rays delivered at a slower rate upon the conditioned avoidance behavior of primates. Washington, D. C., Walter Reed Army Institute of Research Report TR4, 1965.
8. Young, R. J., Chapman, P. H., Barnes, D. J., Brown, G. C. and Hurst, C. M. Behavioral and physiologic responses of Macaca mulatta monkeys to supra-lethal doses of radiation. Brooks Air Force Base, Texas, U. S. Air Force School of Aerospace Medicine Report TR68-73, 1968.
9. Young, R. W. and Kessler, D. A. Performance of sequential tasks by unrestrained monkeys following a 4200-rad pulse of mixed gamma-neutron radiation. Bethesda, Maryland, Armed Forces Radiobiology Research Institute Scientific Report SR69-14, 1969.

## DISTRIBUTION LIST

### AIR FORCE

The Surgeon General, U. S. Department of the Air Force, Washington, D. C. 20333 (1)  
Executive Officer, Director of Professional Services, Office of the Surgeon General, Hq. USAF (AFMSPA) T-8, Washington, D. C. 20333 (1)  
Headquarters, U. S. Air Force (AFMSPAB), Washington, D. C. 20333 (1)  
Chief, Radiobiology Branch, USAF School of Aerospace Medicine, Aerospace Medical Division (AFSC), Brooks AFB, Texas 78235 (2)  
Air Force Weapons Laboratory, ATTN: WLIL (1), ATTN: WLRB-2 (1), Kirtland AFB, New Mexico 87117 (2)  
Chief, Nuclear Medicine Department, P. O. Box 5088, USAF Hospital, Wright-Patterson AFB, Ohio 45433 (1)  
Commander, 6571st Aeromedical Research Laboratory, Holloman AFB, New Mexico 88330 (2)  
Office of the Command Surgeon (ADCSG), Hq. Aerospace Defense Command, USAF, Ent AFB, Colorado 80912 (1)

### ARMY

The Surgeon General, U. S. Department of the Army, Washington, D. C. 20315 (1)  
Surgeon General, ATTN: MEDDH-N, U. S. Department of the Army, Washington, D. C. 20315 (1)  
Commandant, U. S. Army Chemical Center and School, ATTN: AJMCL-T, Fort McClellan, Alabama 36201 (1)  
USACDC CSSG, Doctrine Division, Fort Lee, Virginia 23801 (1)  
Commanding Officer, U. S. Army Combat Developments Command, Institute of Nuclear Studies, Fort Bliss, Texas 79916 (1)  
CG, USCONARC, ATTN: ATUTR-TNG (NBC), Fort Monroe, Virginia 23351 (1)  
Commanding General, U. S. Army Electronics Command, ATTN: AMSEL-RD-MAT, Fort Monmouth, New Jersey 07703 (1)  
Nuclear Branch AMCRD-DN-RE, U. S. Army Materiel Command, Washington, D. C. 20315 (1)  
Commanding Officer, U. S. Army Medical Research Laboratory, Fort Knox, Kentucky 40121 (1)  
U. S. Military Academy, ATTN: Document Library, West Point, New York 10996 (1)  
Commanding Officer, USA Nuclear Medical Research Detachment, Europe, APO New York, N. Y. 09180 (2)  
Army Research Office, ATTN: Chief, Scientific Analysis Branch, Life Sciences Division, 3045 Columbia Pike, Arlington, Virginia 22204 (1)  
Division of Nuclear Medicine, Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, D. C. 20012 (5)  
Commanding Officer, U. S. Army Environmental Hygiene Agency, ATTN: USAEHA-RP, Edgewood Arsenal, Maryland 21010 (1)  
Commandant, U. S. Army Medical Field Service School, ATTN: MEDEW-ZNW, Fort Sam Houston, Texas 78234 (1)

### NAVY

Chief, Bureau of Medicine and Surgery, U. S. Navy Department, Washington, D. C. 20390 (1)  
Chief, Bureau of Medicine and Surgery, ATTN: Code 71, U. S. Navy Department, Washington, D. C. 20390 (1)  
Commanding Officer, Naval Aerospace Medical Institute, U. S. Naval Aviation Medical Center, ATTN: Director of Research, Pensacola, Florida 32512 (3)  
Head, Animal Behavioral Sciences Branch, Naval Aerospace Medical Institute, Naval Aerospace Medical Center, ATTN: Dr. John S. Thach, Jr., Pensacola, Florida 32512 (1)  
Commanding Officer, Nuclear Weapons Training Center, Atlantic, Nuclear Warfare Department, Norfolk, Virginia 23511 (1)  
Commanding Officer, Nuclear Weapons Training Center, Pacific, U. S. Naval Air Station, North Island, San Diego, California 92135 (1)  
Commanding Officer, Naval Submarine Medical Center, Naval Submarine Base, NL, ATTN: Medical Library, Groton, Connecticut 06340 (1)  
Commanding Officer, Naval Submarine Medical Center, Naval Submarine Base, NL, ATTN: Code 53, Nuclear Medicine Training Division, Groton, Connecticut 06340 (1)

### D. O. D.

Director, Defense Atomic Support Agency, Washington, D. C. 20305 (1)  
Director, Defense Atomic Support Agency, ATTN: DDST, Washington, D. C. 20305 (1)  
Director, Defense Atomic Support Agency, ATTN: Chief, Medical Directorate, Washington, D. C. 20305 (4)  
Director, Defense Atomic Support Agency, ATTN: Technical Library (APTL), Washington, D. C. 20305 (2)  
Commander, Field Command, Defense Atomic Support Agency, ATTN: FC Technical Library, Sandia Base, Albuquerque, New Mexico 87115 (1)  
Commander, Headquarters Field Command, Defense Atomic Support Agency, ATTN: FCTG8, Sandia Base, Albuquerque, New Mexico 87115 (2)  
Director, Armed Forces Institute of Pathology, Washington, D. C. 20305 (1)  
Administrator, Defense Documentation Center, Cameron Station, Bldg. 5, Alexandria, Virginia 22314 (20)

## OTHER GOVERNMENT

- U. S. Atomic Energy Commission, Headquarters Library, Reports Section, Mail Station G-17, Washington, D. C. 20545 (1)
- U. S. Atomic Energy Commission, Division of Biology and Medicine, Washington, D. C. 20545 (1)
- U. S. Atomic Energy Commission, Bethesda Technical Library, 7920 Norfolk Avenue, Bethesda, Maryland 20014 (1)
- National Aeronautics and Space Administration, ATTN: Lt. Col. Charles M. Barnes, USAF, DB-3, MSC, Houston, Texas 77058 (1)
- National Aeronautics and Space Administration, Manned Spacecraft Center, ATTN: Dr. B. D. Newsom, Mail Code DA, Houston, Texas 77058 (1)
- National Library of Medicine, Bethesda, Maryland 20014 (1)
- U. S. Public Health Service, Bureau of Radiological Health, Division of Biological Effects, 12720 Twinbrook Parkway, Rockville, Maryland 20852 (1)
- U. S. Public Health Service, Bureau of Radiological Health, Library, 12720 Twinbrook Parkway, Rockville, Maryland 20852 (1)
- U. S. Public Health Service, Northeastern Radiological Health Laboratory, 109 Holton Street, Winchester, Massachusetts 01890 (1)
- U. S. Public Health Service, Southeastern Radiological Health Laboratory, P. O. Box 61, Montgomery, Alabama 36101 (1)
- U. S. Public Health Service, Southwestern Radiological Health Laboratory, P. O. Box 15027, Las Vegas, Nevada 89114 (1)

## OTHER

- Argonne National Laboratory, Library Services Department, Report Section Bldg. 203, RM-CE-125, 9700 South Cass Avenue, Argonne, Illinois 60440 (1)
- Boeing Company Aerospace Library, ATTN: 8K-38 Ruth E. Peerenboom, P. O. Box 3999, Seattle, Washington 98124 (2)
- Dr. J. T. Brennan, Radiology Department, University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104 (1)
- Brookhaven National Laboratory, Information Division, ATTN: Research Library, Upton, Long Island, New York 11973 (2)
- Dr. J. S. Burkle, Director of Nuclear Medicine, York Hospital, York, Pennsylvania 17403 (1)
- University of California, Lawrence Radiation Laboratory, Library, Bldg. 50, Room 134, Berkeley, California 94720 (1)
- Director, Radiobiology Laboratory, University of California, Davis, California 95616 (1)
- University of California, Lawrence Radiation Laboratory, Technical Information Division Library L-3, P. O. Box 808, Livermore, California 94551 (2)
- University of California, Laboratory of Nuclear Medicine and Radiation Biology, Library, 900 Veteran Avenue, Los Angeles, California 90024 (1)
- Cdr. William H. Chapman, USN (Ret.), Bio-Medical Division L-523, Lawrence Radiation Laboratory, University of California, P. O. Box 808, Livermore, California 94551 (1)
- Director, Collaborative Radiological Health Laboratory, Colorado State University, Fort Collins, Colorado 80521 (1)
- Dr. L. W. Davis, Radiology Department, University of Pennsylvania, 3400 Spruce Street, Philadelphia, Pennsylvania 19104 (1)
- Dr. T. C. Evans, Radiation Research Laboratory, College of Medicine, University of Iowa, Iowa City, Iowa 52240 (1)
- Mr. Orin Gelderloos, Division of Literature, University of Michigan, Dearborn Campus, Dearborn, Michigan 48124 (1)
- General Dynamics/Fort Worth, ATTN: Librarian, P. O. Box 748, Fort Worth, Texas 76101 (1)
- Gulf General Atomic Incorporated, ATTN: Library, P. O. Box 608, San Diego, California 92112 (1)
- IIT Research Institute, ATTN: Document Library, 10 West 35th Street, Chicago, Illinois 60616 (1)
- Los Alamos Scientific Laboratory, ATTN: Report Librarian, P. O. Box 1663, Los Alamos, New Mexico 87544 (1)
- Director, Nuclear Science Center, Louisiana State University, Baton Rouge, Louisiana 70803 (2)
- Lovelace Foundation for Medical Education and Research, Document Library, 5200 Gibson Boulevard, S. E., Albuquerque, New Mexico 87108 (1)
- Dr. Ross A. McFarland, Guggenheim Professor of Aerospace Health and Safety, Harvard School of Public Health, 665 Huntington Avenue, Boston, Massachusetts 02115 (1)
- Dr. J. I. Marcum, Rand Corporation, 1700 Main Street, Santa Monica, California 90401 (1)
- Massachusetts Institute of Technology, M. I. T. Libraries, Technical Reports, Room 14 E-210, Cambridge, Massachusetts 02139 (1)
- Dr. Harvey M. Patt, Laboratory of Radiobiology, University of California, San Francisco Medical Center, San Francisco, California 94122 (1)



#### OTHER (continued)

Purdue University, Nuclear Engineering Library, Lafayette, Indiana 47907 (1)  
Dr. S. M. Reichard, Director, Division of Radiobiology, Medical College of Georgia, Augusta, Georgia 30902 (1)  
University of Rochester, Atomic Energy Project Library, P. O. Box 287, Station 3, Rochester, New York 14620 (1)  
Dr. H. H. Rossi, 630 West 168th Street, New York, N. Y. 10032 (1)  
Dr. E. L. Saenger, Director, Radioisotope Laboratory, Cincinnati General Hospital, Cincinnati, Ohio 45229 (1)  
Sandia Corporation Library, P. O. Box 5800, Albuquerque, New Mexico 87115 (1)  
Scope Publications, Franklin Station, P. O. Box 7407, Washington, D. C. 20004 (1)  
Texas A. and M. University, Radiation Biology Laboratory, Texas Engineering Experiment Station, College Station, Texas 77840 (2)  
Texas Nuclear Corporation, ATTN: Director of Research, Box 9267 Allandale Station, Austin, Texas 78756 (1)  
Western Reserve University, Department of Radiology, Division of Radiation Biology, Cleveland, Ohio 44106 (1)  
Mr. Lionel Zamore, 601 Brightwater Court, Brooklyn, New York 11235 (1)

#### FOREIGN

International Atomic Energy Agency, Kärrntnerring 11, Vienna I, 1010, Austria (1)  
National Lending Library for Science and Technology, Boston Spa, Yorkshire, England (1)  
Directorate of Medical and Health Services, FAF (Federal Armed Forces), Bonn, Ermekeilstrasse 27, West Germany (1)  
Abteilung für Strahlenbiologie im Institut für Biophysik der Universität Bonn, 53 Bonn-Venusberg, Annaberger Weg 15, Federal Republic of Germany (2)  
Prof. Dr. H. Langendorff, Direktor des Radiologischen Instituts der Universität, 78 Freiburg im Breisgau, Albertstrasse 23, Germany (1)  
Priv.-Doz. Dr. O. Messerschmidt, Radiologisches Institut der Universität, 78 Freiburg im Breisgau, Albertstrasse 23, Germany (1)  
Dr. Helmut Mitschrich, Akademie des Sanitäts- und Gesundheitswesens der Bundeswehr, Spezialstab ATV, 8 München, Schwere Reiterstrasse 4, Germany (2)  
Prof. Dr. F. Wachsmann, Gesellschaft für Strahlenforschung m.b.H., 8042 Neuherberg bei München, Institut für Strahlenschutz, Ingolstadter Landstrasse 1, München, Germany (1)  
Col. Joachim Emde, Direktor, Spezialstab ATV, ABC- und Selbstschuttschule, 8972 Sonthofen 2/Allgäu, Berghoferstrasse 17, West Germany (1)  
Puerto Rico Nuclear Center, ATTN: Reading Room, College Station, Mayaguez, Puerto Rico 00708 (2)

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Armed Forces Radiobiology Research Institute Defense Atomic Support Agency Bethesda, Maryland 20014		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP N/A	
3. REPORT TITLE  THE EFFECTS OF 15,000 RADS PULSED GAMMA-NEUTRON RADIATION ON THE BEHAVIORAL PERFORMANCE OF MONKEYS ( <u>MACACA MULATTA</u> )			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name)  R. W. Young and W. L. McFarland			
6. REPORT DATE June 1970		7a. TOTAL NO. OF PAGES 11	7b. NO. OF REFS 9
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S) AFRRI SR70-7	
b. PROJECT NO. NWER XAXM			
c. Task and Subtask A 904		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d. Work Unit 02			
10. DISTRIBUTION STATEMENT  This document has been approved for public release and sale; its distribution is unlimited			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Director Defense Atomic Support Agency Washington, D. C. 20305	
13. ABSTRACT  Seven male monkeys trained to a visual discrimination task were exposed to a pulsed 15,000-rad midline tissue dose of gamma-neutron radiation. Of these seven animals, five were unable to perform within 5 minutes postirradiation and remained in a state of total nonperformance until death. The two remaining animals experienced periods of severe performance decrement followed by a return of performance capability which approached the preirradiation value. This performance capability deteriorated rapidly at 58 and 88 minutes postirradiation in these two animals, after which time the subjects failed to perform until death. The median survival time for all animals was 1 hour and 18 minutes.			